Supported by

U.S. DEPARTMENT OF ENERGY | Office of Science

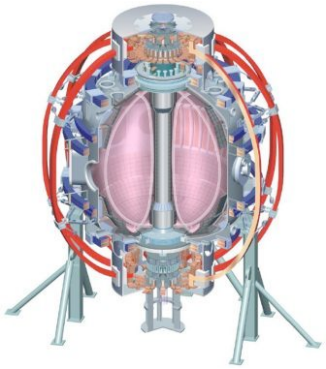
"Snowflake" divertor in NSTX

Vlad Soukhanovskii, *LLNL*

in collaboration with

D. D. Ryutov, *LLNL*
D.A. Gates, S. Gerhardt, J.E. Menard, S. Zweben, *PPPL*
R. Maingi, J.-W. Ahn, *ORNL*
R. Maqueda, *Nova Photonics*

NSTX Team XP Review
Princeton, NJ
July 22, 2009

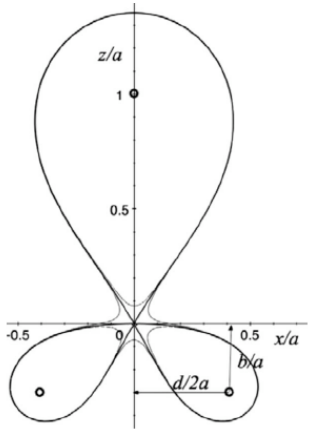


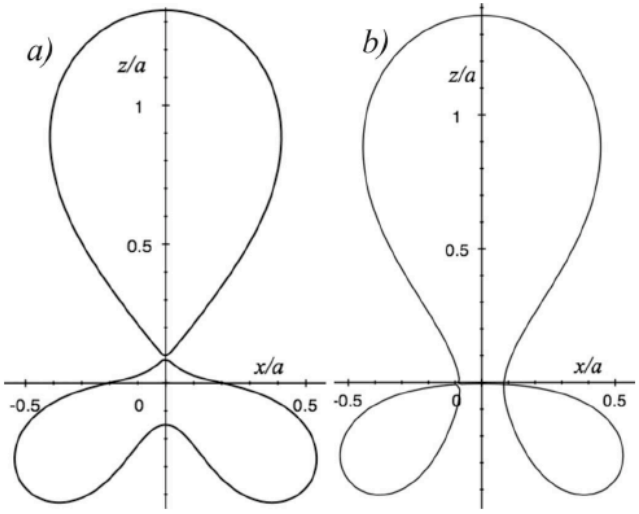
College W&M
Colorado Sch Mines
Columbia U
Comp-X
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
PSI
Princeton U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Maryland
U Rochester
U Washington
U Wisconsin

Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
KBSI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

"Snowflake" divertor configuration: theory predicts numerous edge physics benefits

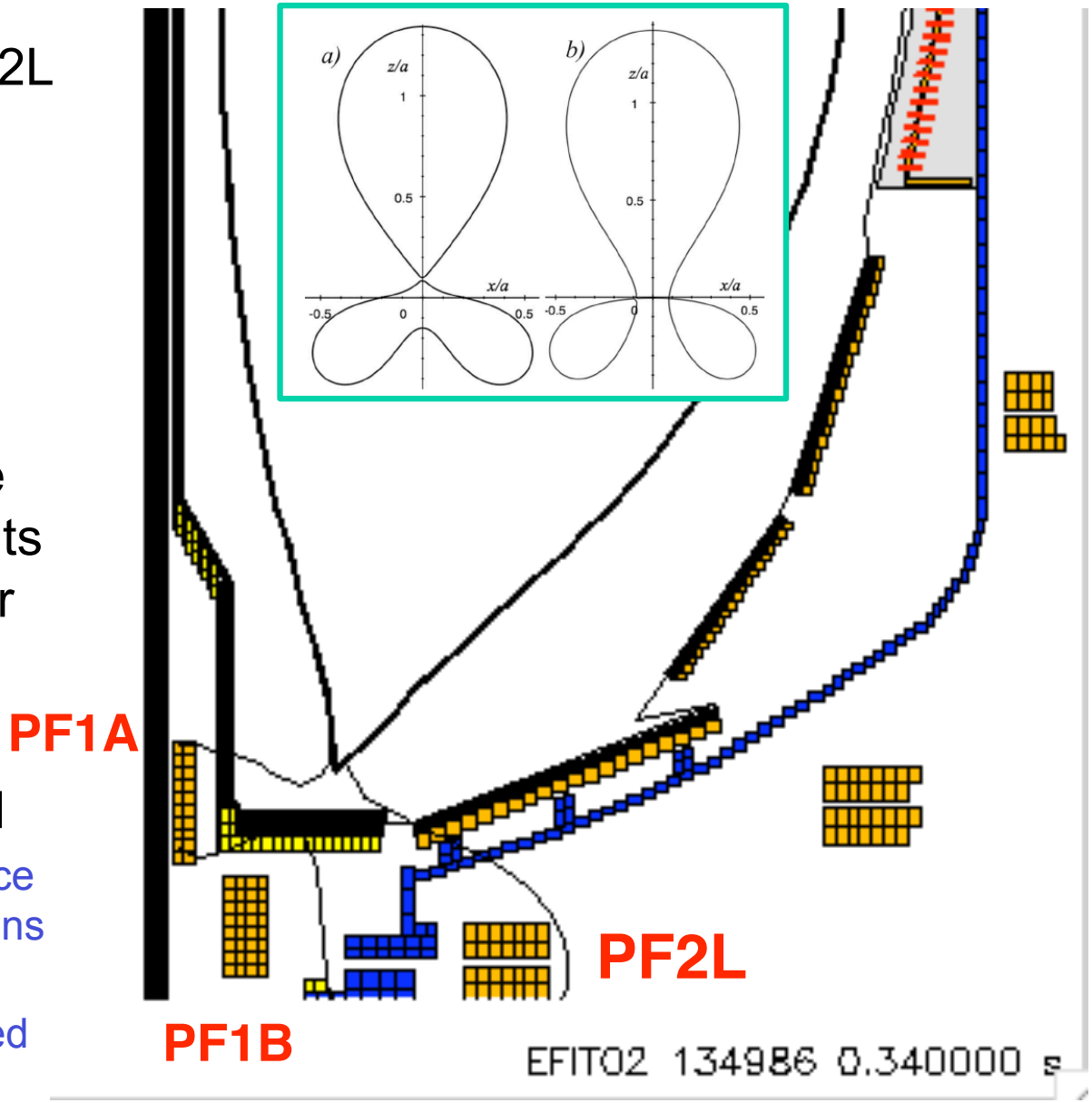
- "Snowflake" divertor (SFD) configuration proposed and theoretically studied by D. D. Ryutov (LLNL) (Phys. Plasmas 14, 064502 (2007); Phys. Plasmas, **15, 092501 (2008),** paper IC/P4-8 at IAEA FEC 2008)
- SFD obtained by creating a second-order poloidal null
- Two cases – SFD-plus and SFD-minus
- Predicted properties
  - Large flux expansion (***B*_p/*B*** small)
    - Divertor peak heat flux reduction
  - Edge magnetic shear modification
    - Flux tube squeezing – barrier for turbulence
    - Possibility of ELM control





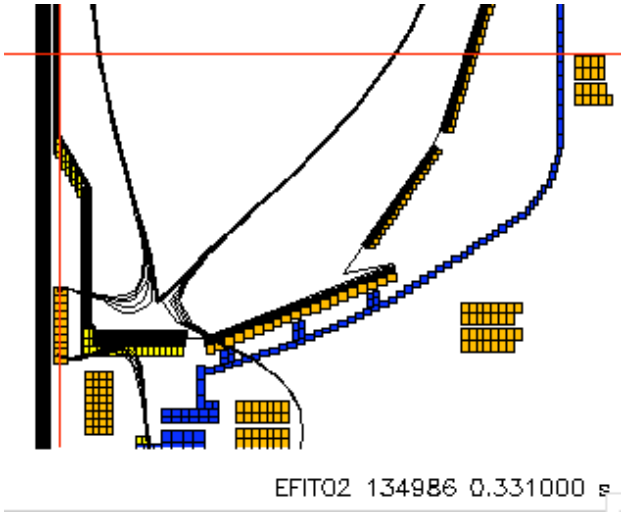
Implementation of SFD in NSTX

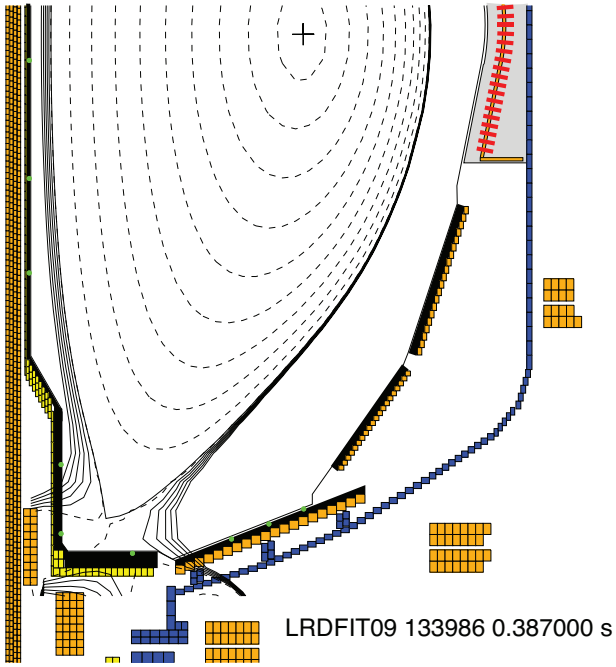
- Two coils PF1A and PF2L
- Coil PF1B is not useful unless its current is reversed – not trivial
- Initially, do not use any control algorithms – use pre-programmed currents to collect data for further ISOLVER modeling
- Two paths are identified
  - Use fiducial shot, introduce pre-programmed deviations
  - Use shot from XP 904, introduce pre-programmed deviations

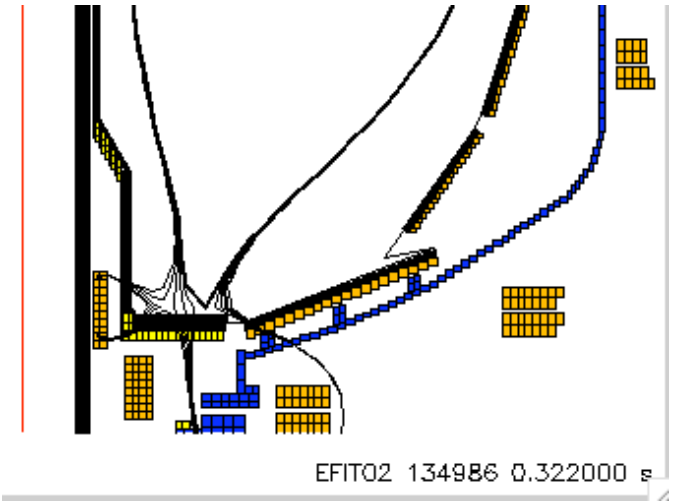


SFD has been transiently achieved in NSTX

- Medium triangularity shots from XP 904
- Calculated flux expansion 30-70
- Challenge is to demonstrate steady-state configuration

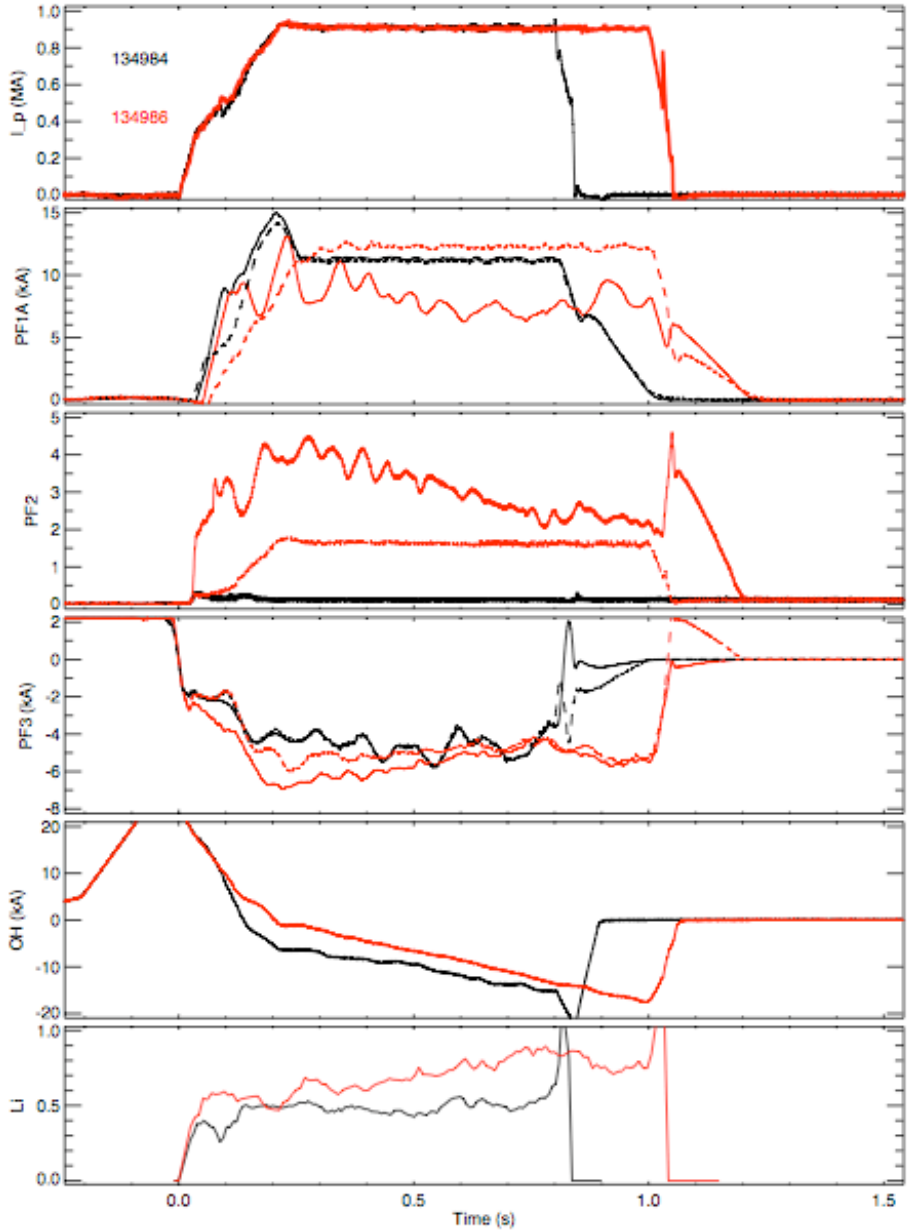




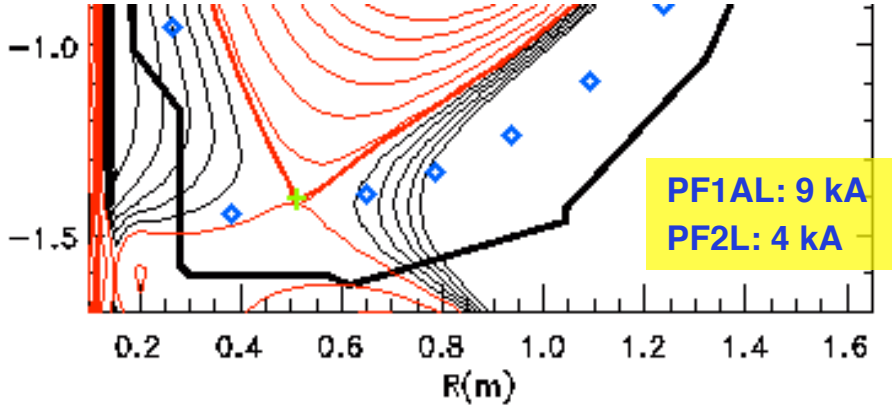


Scenario 1: Start from a shot from XP 904 (Kolemen)

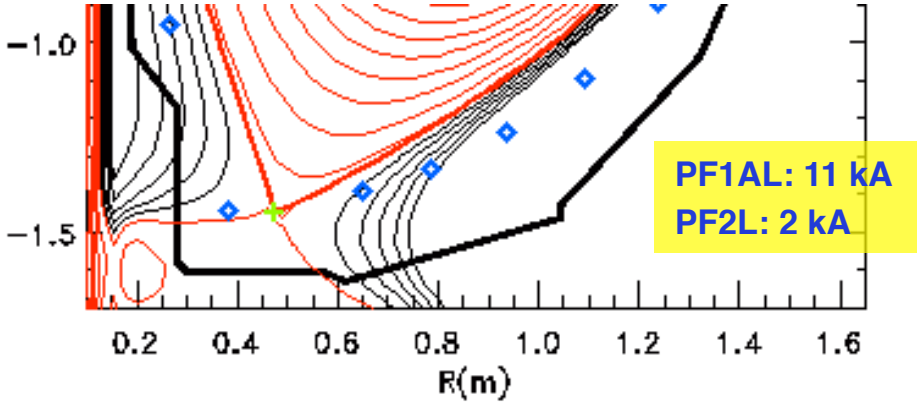
- Fiducial coil currents in black, XP 904 shot in red
- XP 904 coil currents (in flattop):
  - PF1A L – 7-9 kA
  - PF2 L – 2-4 kA
  - PF3 (L, U) – 4-6 kA
- Reproduce the shot
- Adjust PF1A and PF2L currents in 1-2 kA increments to bring two lower X-points closer



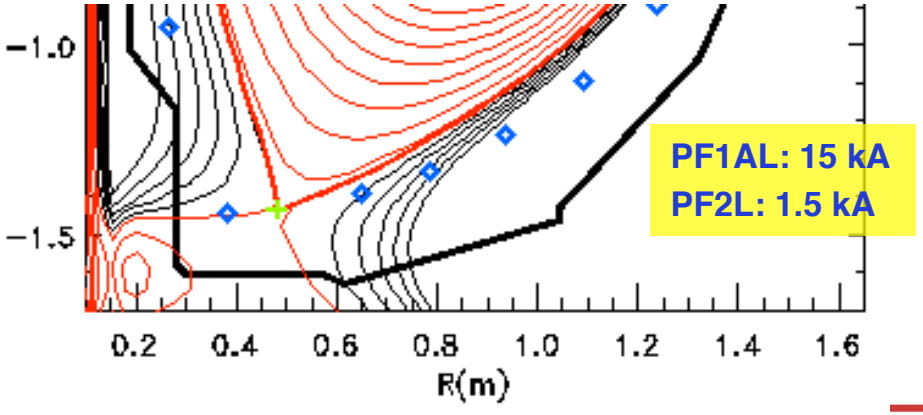
ISOLVER modeling shows configuration trends when both PF1A and PF2L coil currents are varied



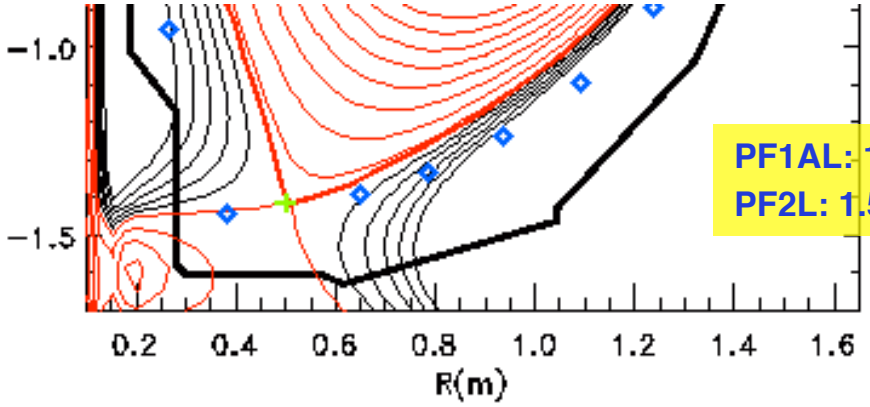
PF1AL: 9 kA
PF2L: 4 kA



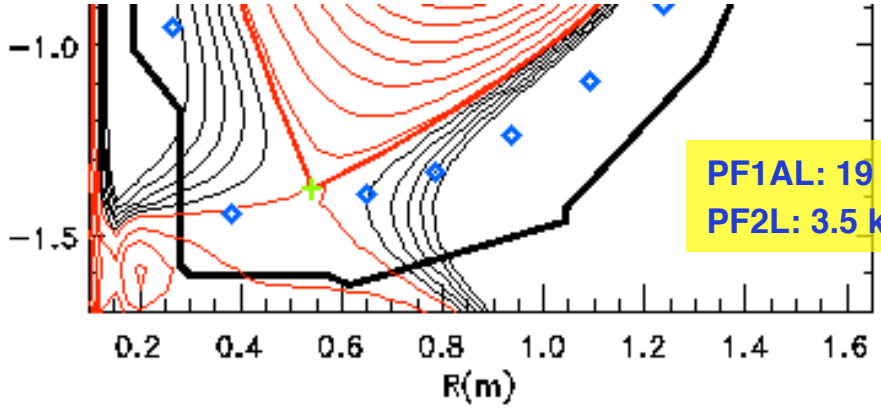
PF1AL: 11 kA
PF2L: 2 kA



PF1AL: 15 kA
PF2L: 1.5 kA



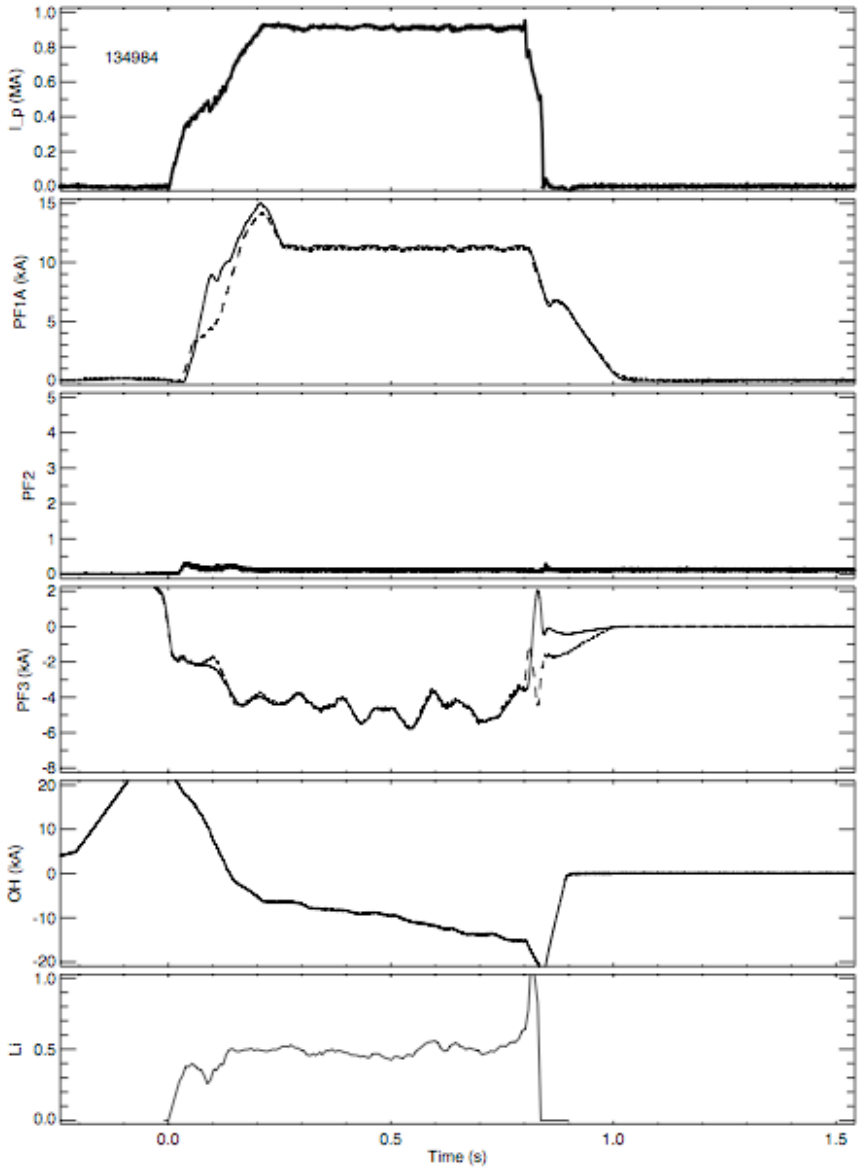
PF1AL: 19 kA
PF2L: 1.5 kA

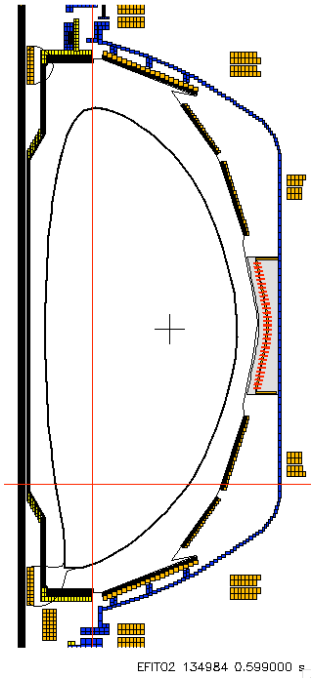


PF1AL: 19 kA
PF2L: 3.5 kA

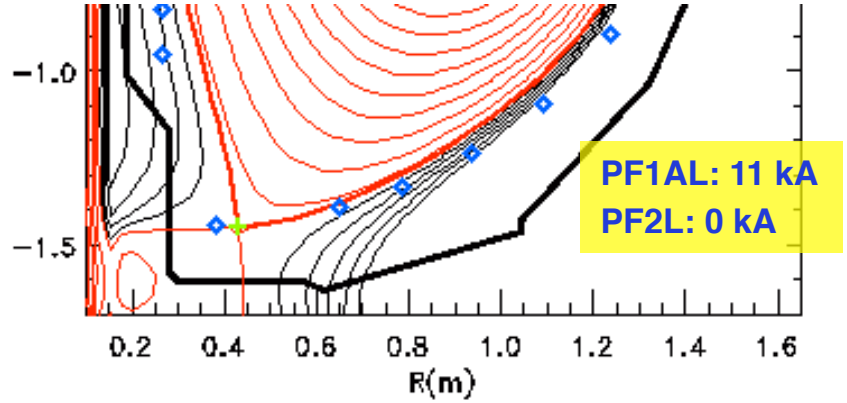
Scenario 2: Start from PF1A fiducial, add PF2L

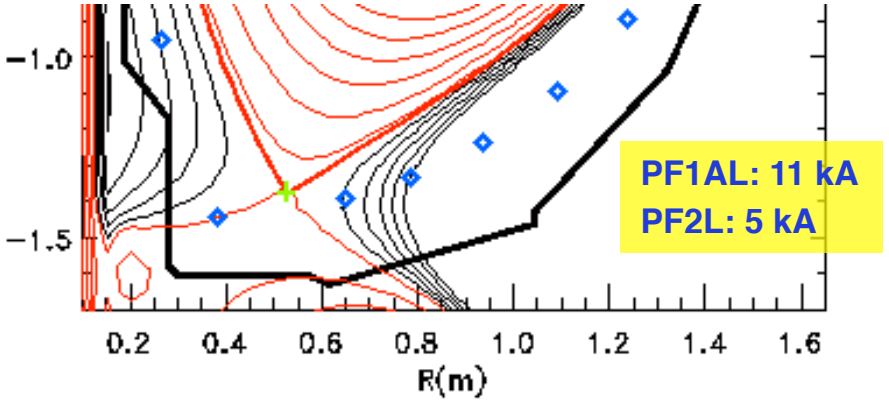
- Fiducial coil currents in flattop:
  - PF1A (L, U) – 11 kA
  - PF2 (L, U) – 0 kA
  - PF3 (L, U) – 4-5 kA
- Start ramping up PF2L at 0.23-0.25 s, and bring it to 3-6 kA in increments of 1 kA on a shot-to-shot basis
- May need to adjust PF1AL within 5-15 kA

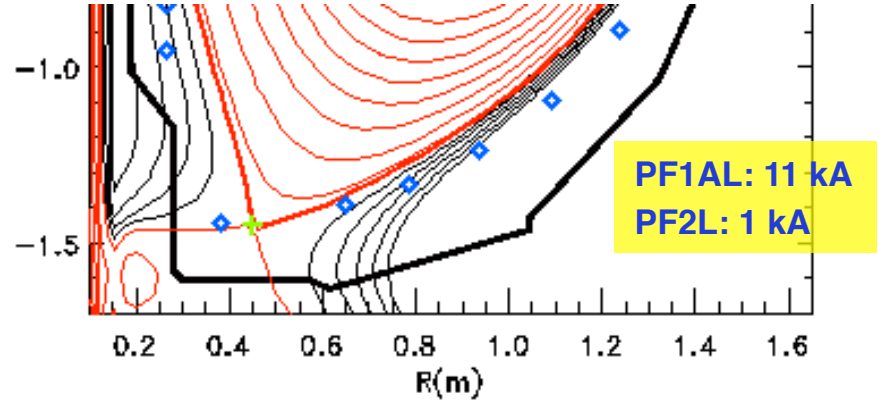


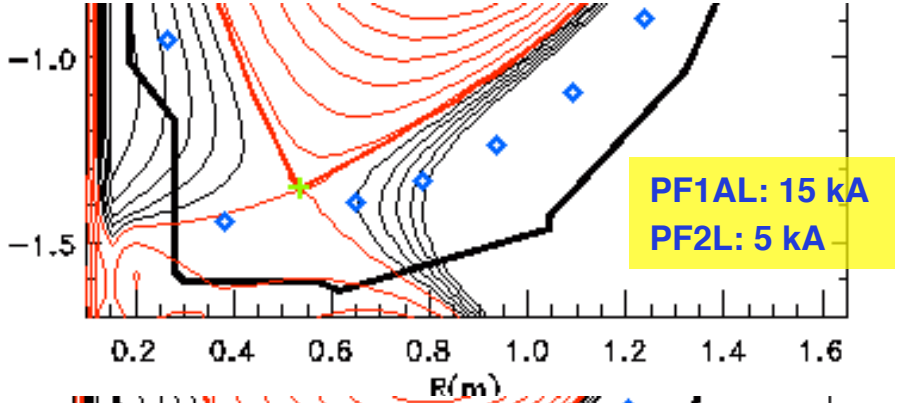


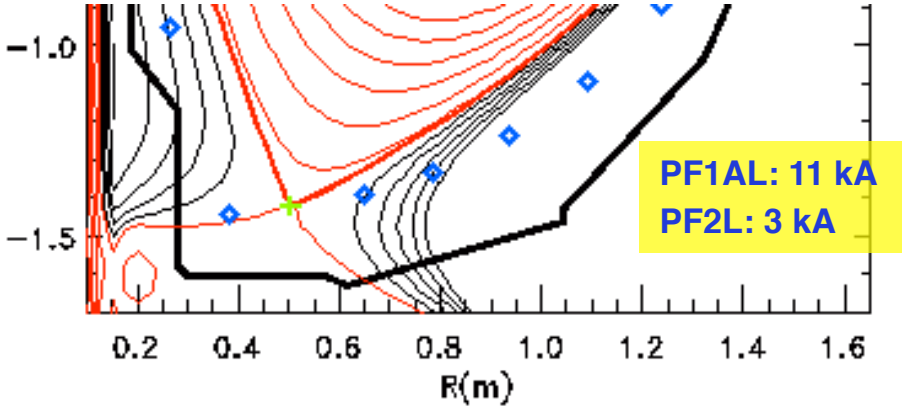
ISOLVER modeling shows configuration trends when PF2L is added to the PF1A fiducial LSN configurtion

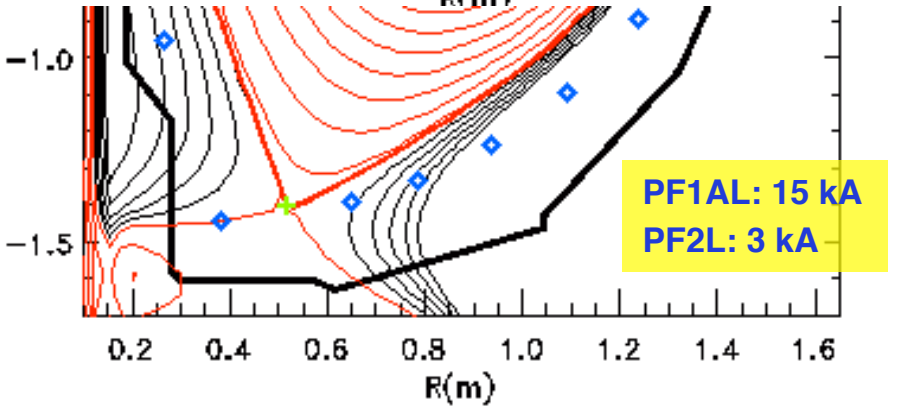












SFD experimental effort on NSTX

- NSTX divertor diagnostic set is particularly suited to characterizing SFD
  - Measure divertor heat and particle fluxes (IR cameras, Da, LPs), impurity profiles, sources, radiation (bolometers, spectroscopy)
  - Measure divertor turbulence characteristics and flux tube squeezing (Ricky's fast tangential divertor camera, midplane GPI)
- Potential to demonstrate coupling between theory and experiment
- Plan for FY 2009
  - Start experiments with pre-programmed coil currents
  - Obtain initial characterization
  - Produce initial UEDGE modeling to guide future experiments
- Plan for FY 2010
  - Develop and run SFD experiments with PCS control
  - Characterize control and stability of SFD configuration
  - Obtain full transport and turbulence evaluation of several configurations

Run plan for ½ day in FY 2009

- Start with scenario 1, adjust currents to obtain SFD
  - PF1A range 0.005 -0.020 (in terms of I_{PF1A}/I_p)
  - PF2L range 0.00125-0.00875
  - Lower δ = 0.55-0.6, κ=2.1-2.3, drsep ~ -0.005-0.01
  - I_p=0.8-0.9 MA, P_{NBI}=4-6 MW, moderate lithium (< 10 mg/min) if necessary
  - Use PCS for GAPOUT control
  - If possible, keep OSP at R < 0.55 m (on the horizontal plate) to address concerns of putting power in the CHI gap
  - If necessary, adjust "X-point box" to avoid two X-point confusion for PCS
- If necessary, can start from a fiducial (scenario 2)
- Obtain a "reference" discharge with "standard" divertor configuration to compare